IJDACR
ISSN: 2319-4863

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 6, January 2017)

A Hybrid Scheme for PAPR Reduction using DCT, PTS and Companding Techniques

Naveena Choudhary
M. E. Student
MITS, Gwalior
naveena.choudhary@gmail.com

Dr. Karuna Markam
Assistant professor
MITS, Gwalior
karuna_markam@rediffmail.com

Abstract –**OFDM is successfully used in many wireless digital communication system over multipath channels. One of the principle disadvantages of OFDM is the occurrence of high PAPR. OFDM signals are very sensitive to nonlinear effects due to the high PAPR, which leads to the power inefficiency in the RF section of the transmitter. This paper is focused on analyzing PAPR reduction by undertaking various methods to reduce the PAPR in the system PTS, Companding and a hybrid DCT-PTS-Companding. Simulation results show that the proposed hybrid method outperforms other methods of PAPR reduction.**

Keywords –**Companding, DCT, ICI, ISI, OFDM, PAPR, PTS.**

I. Introduction

With the advent of new high data rate wireless applications, demand of the spectrum is rapidly increasing. Communications governmental and regulatory agencies impose regulations on spectrum usage, such as control of allocations and priorities, as well as its features. At this time, most of the prime spectrum has been assigned and it is difficult to find spectrum for the new wireless applications [1]. It can be made available for either expands existing infrastructures or invent new services. Orthogonal Frequency Division Multiplexing (OFDM) is promising candidate for flexible spectrum pooling in communication systems [2].

For a long time, usage of OFDM in practical systems was limited. Main reasons for this limitation were the complexity of real time Fourier Transform and the linearity required in RF power amplifiers. However since 1990s, OFDM is used for wideband data communications over mobile radio FM channels, High-bit-rate Digital Subscriber Lines (HDSL, 1.6Mbps), Asymmetric Digital Subscriber Lines (ADSL, up to 6Mbps), Very-high-speed Digital Subscriber Lines (VDSL, 100Mbps), Digital Audio Broadcasting (DAB), and High Definition Television (HDTV) terrestrial broadcasting [2].

OFDM has many advantages over single carrier systems. The implementation complexity of OFDM is significantly lower than that of a single carrier system with equalizer. When the transmission bandwidth exceeds coherence bandwidth of the channel, resultant distortion may cause intersymbol interference (ISI) [3]. Single carrier systems solve this problem by using a linear or nonlinear equalization. The problem with this approach is the complexity of effective equalization algorithms. OFDM systems divide available channel bandwidth into a number of subchannels [4]. By selecting the subchannel bandwidth smaller than the coherence bandwidth of the frequency selective channel, the channel appears to be nearly flat and no equalization is needed. Also by inserting a guard time at the beginning of OFDM symbol during which the symbol is cyclically extended, intersymbol interference (ISI) and intercarrier interference (ICI) can be completely eliminated, if the duration of guard period is properly chosen. This property of OFDM makes the single frequency networks possible [4]. In single frequency networks, transmitters simultaneously broadcast at the same frequency, which causes intersymbol interference. Additionally, in relatively slow time varying channels, it is possible to significantly enhance the capacity by adapting the data rate per subcarrier according to the signal-to-noise ratio (SNR) of that particular subcarrier. Another advantage of OFDM over single carrier systems is its robustness against narrowband interference because such interference affects only a small percentage of the subcarriers [4].

Beyond all these advantages, OFDM has some drawbacks compared to single carrier systems. Two of the problems with OFDM are the carrier phase noise and frequency offset. Carrier phase noise is caused by imperfections in the transmitter and receiver oscillators. Frequency offsets are created by differences between oscillators in transmitter and receiver, Doppler shifts, or phase

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 6, January 2017)

noise introduced by nonlinear channels. There are two destructive effects caused by a carrier frequency offset in an OFDM system. One is the reduction of signal amplitude *sinc* functions are shifted and no longer sampled at the peak, and the other is the introduction of ICI from the other carriers. The latter is caused by the loss of Orthogonality between the subchannels. Sensitivity to phase noise and frequency offsets increases with the number of subcarriers and with the constellation size used for subcarrier modulation. For single carrier systems, phase noise and frequency offsets only give degradation in the receiver SNR, rather than introducing ICI. That is why the sensitivity to frequency offsets and phase noise are mentioned as disadvantages of OFDM relative to single carrier systems [4].

The most important disadvantage of OFDM systems is that highly linear RF amplifiers are needed. An OFDM signal consists of a number of independently modulated subcarriers, which can give a large Peak-to-Average Power Ratio (PAPR) when added up coherently [5]. When N signals are added with the same phase, they produce a peak power that is N times the average power. In order to avoid nonlinear distortion, highly linear amplifiers are required which cause a severe reduction in power efficiency. Several methods are explained in the literature in order to solve this problem [6-16].

One of the challenges of the OFDM is high peak-to-average power ratio (PAPR). A high PAPR brings disadvantages like an increased complexity of the A/D and D/A converters and reduced efficiency of radio frequency (RF) power amplifier [14].

OFDM signal consists of a number of independent modulated subcarriers that leads to the problem of PAPR. If all subcarriers come with same phase, the peak power is N times the average power of the signal where N is the total number of symbols in an OFDM signal. Thus, it is not possible to send this high peak amplitude signals to the transmitter without reducing peaks. Because power amplifier used for the transmission has non-linear nature which causing inter-modulation and out-of-band radiation.

The high peak of OFDM signal can be reduced in several ways. Most widely used methods are clipping and peak windowing the OFDM signal when a high PAPR is encountered. However these methods distort the original OFDM signal resulting in an increase in the bit error probability. There are other methods that do not distort the signal.

In this research work a peak-to-average-ratio (PAPR) reduction scheme based on a weighted orthogonal frequency-division multiplexing (OFDM) signal is proposed to reduce the PAPR without distortion in removing the weight at the receiver side.

In the proposed scheme, a weight is imposed on each discrete OFDM signal via a certain kind of a bandlimited signal, and an OFDM signal formed with the weighted discrete data is then considered before a high power amplifier (HPA), whereas the original signal can be recovered completely at the receiver side. Meanwhile, the time duration needed to transmit the weighted OFDM signal is the same as the time duration for the original OFDM signal. Coding is another commonly used method. In this case the information bits are coded in a way that no high peaks are generated. In this research work, convolution codes are used.

PAPR can be described by its complementary cumulative distribution function. In this probabilistic approach certain schemes have been proposed by researchers. These include clipping method, coding and signal scrambling method. Under the heading of signal scrambling techniques there are two schemes included. Which are Partial transmit sequence (PTS) [16] and Selected Mapping (SLM) [15, 17].

Although some techniques of PAPR reduction have been summarize, it is still indeed needed to give a comprehensive review including some motivations of PAPR reductions [13], to compare some typical methods of PAPR reduction through theoretical analysis and simulation results directly, and such as power saving. An effective PAPR reduction technique should be given the best trade-off between the capacity of data rate loss, PAPR reduction and transmission power, implementation complexity and Bit-Error-Ratio performance.

The objective of this paper is to develop a PAPR reduction system using PTS, Companding and Discrete Cosine Transform along with comparative analysis of bit error rate for above-mentioned schemes.

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 6, January 2017)

II. Proposed Method

PAPR Reduction using PTS Scheme

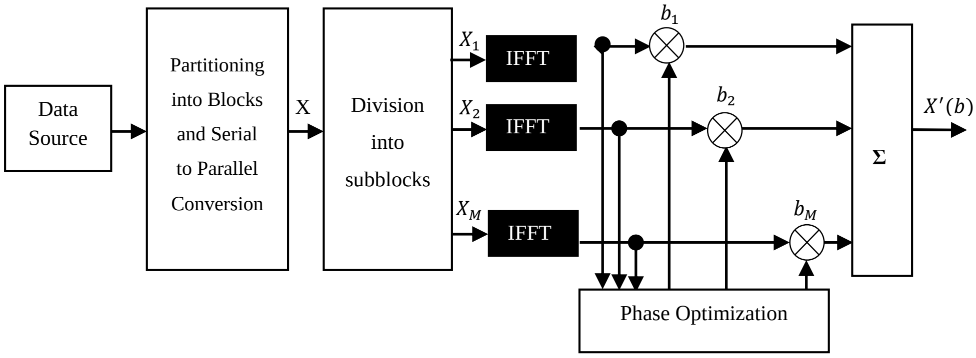

Figure 1: Block diagram of Partial Transmit Sequence method

In the PTS technique, input data block X is partitioned in M disjoint sub-blocks $X_m = [X_{m,0}, X_{m,1}, \ldots\ldots X_{m,N-1}]^T$, $m = 1,2, \ldots\ldots M$, such that $\sum_{m=1}^{M} X_m = X$ and the sub – blocks are combined to minimize the PAPR in the time domain. The L times oversampled time domain signal of X_m, $m = 1,2, \ldots\ldots M$, is obtained by taking the IFFT of length NL on X_m concatenated with $(L-1)N$ zeros. These are called the partial transmit sequences. Complex phase factors, $b_m = e^{j\emptyset m}, m = 1, 2, \ldots\ldots M$ are introduced to combine the PTSs. The set of phase factors is denoted a vector $b = [b_1, b_2, \ldots\ldots. b_M]^T$. The time domain signal after combining is given by

$$x'(b) = \sum_{m=1}^{M} b_m . x_m \quad (1)$$

Where $x'(b) = [x'_0(b), x'_1(b), \ldots\ldots. x'_{NL-1}(b)]^T$.

The objective is to find the set of phase factors that minimizes the PAPR. The optimum signal $x'(b)$ with the lowest PAPR is to be found out.

Both b and x can be shown in matrix form as follows:

$$b = \begin{bmatrix} b_1, b_1 \ldots\ldots b_1 \\ : \ \vdots . \ldots \ldots : \\ b_m, b_m \ldots\ldots b_m \end{bmatrix}_{(M\times N)} \quad (2)$$

$$x = \begin{bmatrix} x_{1,0}, x_{1,1} \ldots\ldots x_{1,NL-1} \\ : \ \vdots . \ldots \ldots : \\ x_{m,0}, x_{m,1} \ldots\ldots x_{m,NL-1} \end{bmatrix}_{(M\times NL)} \quad (3)$$

It should be noted that all the elements of each row of matrix b are of the same values in this method. In order to have exact PAPR calculation, at least 4 times over sampling is necessary. As the over sampling of x, add zeros to the vector, hence the number of phase sequence to multiply to matrix x will remain the same.

The PTS consist of several inverse fast Fourier transform (IFFT) operations and complicated calculations to obtain optimum phase sequence which results in increasing the computational complexity of PTS.

PAPR Reduction using Companding Scheme

The compander consists of compressor and expander. Any invertible function with compression feature can be used for companding [18].

Here we apply the transformation. Because the transformation is invertible, the signal can be recovered in the receiver. First a quadrature demodulator generates the estimate of transformed signals with the aid of receiver signal level control and low pass filter. Using the inverse function of compression, the nonlinear distortion introduced by the compressor is corrected after reconstruction at the receiver with an expander. Compression improves the quantization resolution of small amplitude signals at the cost of lowering the resolution of large signals. This also introduces quantization noise; however, the effect of the quantization noise due to reduction in resolution of the peaks is relatively small as the peaks occur less frequently. The compression algorithm as described by amplifies the signals of lower amplitude with the peaks remaining unchanged.

In companding the OFDM signal is compressed at the transmitter and expanded at the receiver. Compression is performed according to the well-known μ-Law viz.

$$y = V \frac{\log\left[1+\mu\frac{|x|}{V}\right]}{\log(1+\mu)} \mathrm{sgn}(x) \quad (4)$$

Where V is the peak amplitude of the signal, and x is the instantaneous amplitude of the input signal. Decompression is simply the inverse of equation (4). Figure 4 shows concatenation of PTS, Companding and DCT scheme.

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 6, January 2017)

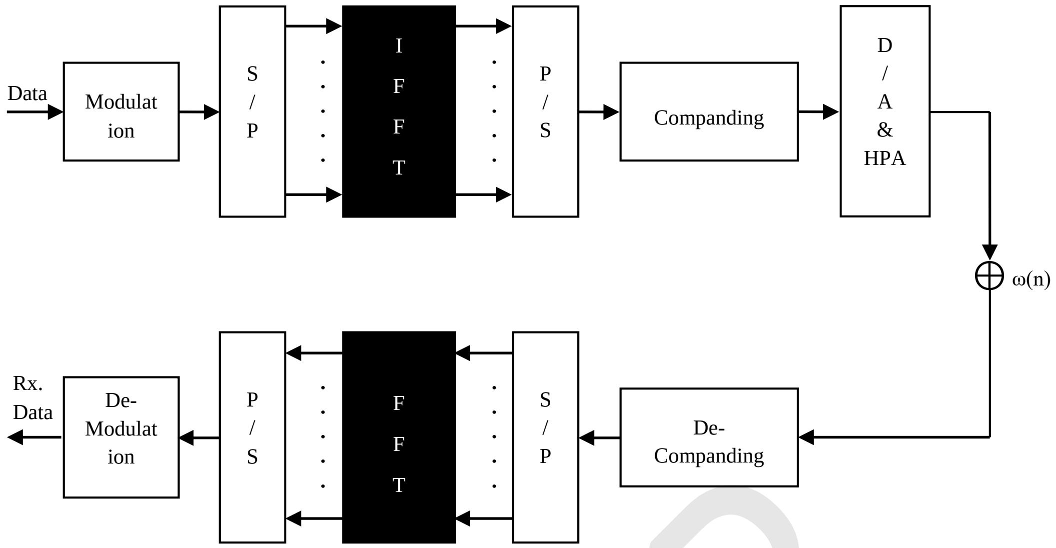

Figure 2: Block diagram of companding transform

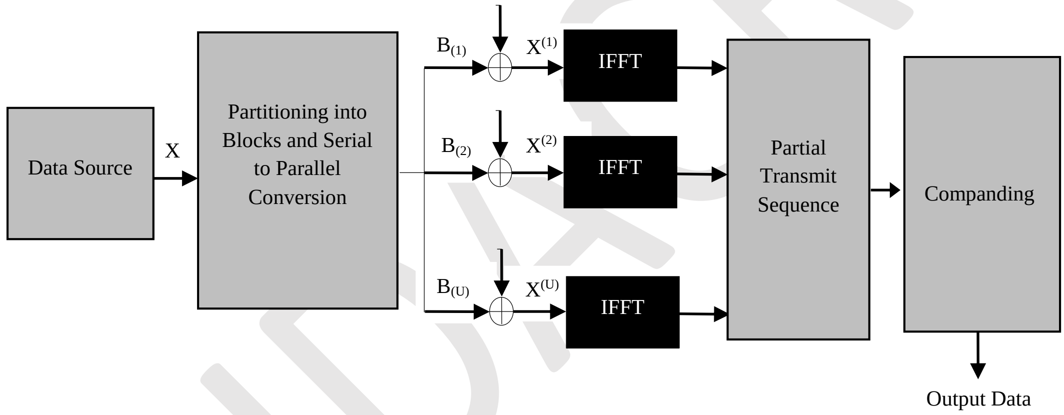

Figure 3: Block diagram of proposed PTS-companding

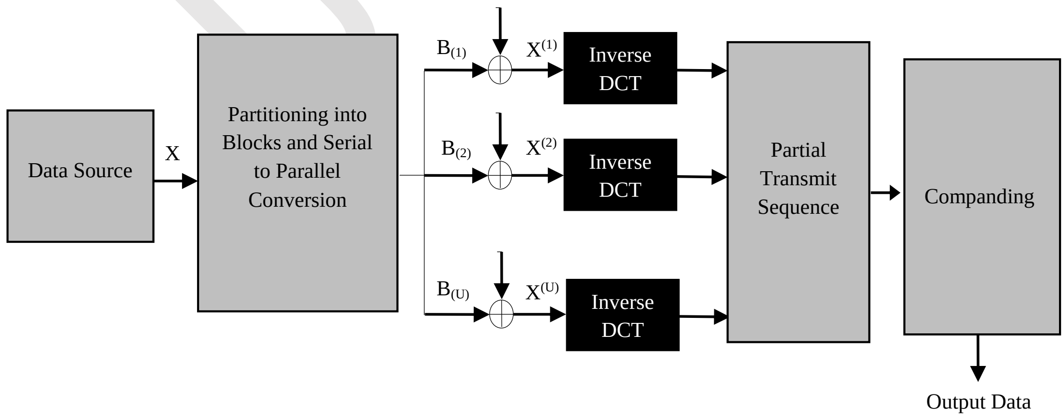

Figure 4: Block diagram of proposed DCT-PTS-companding

Discrete Cosine Transform (DCT)

A DCT is a Fourier related transform similar to Discrete Fourier Transform (DFT) but using only real numbers (since Fourier transform of real and even function is real and even). The DCT is a very popular transform function used in signal

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 6, January 2017)

processing. It transforms a signal from spatial domain to frequency domain. Two dimensional discrete cosine transform (2D-DCT) is defined as:

$$F(jk) = a(j)a(k)\sum_{m=0}^{N-1}\sum_{n=0}^{N-1} f(mn)\cos\left[\frac{(2m+1)j\pi}{2N}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (5)$$

The corresponding inverse transformation (IDCT) is defined as:

$$f(mn) = \sum_{m=0}^{N-1}\sum_{n=0}^{N-1} a(j)a(k)F(jk)\cos\left[\frac{(2m+1)j\pi}{2N}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad (6)$$

The DCT can not only concentrate the main information of original signal into the smallest low frequency coefficient, but also it can cause the signal blocking effect being the smallest, which can realize the good compromise between the information centralizing and the computing complication. So it obtains the wide spreading application in the compression coding.

III. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

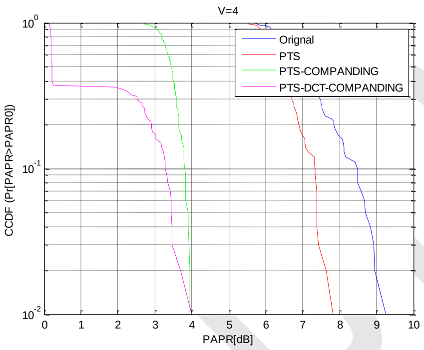

Figure 5: Comparison of different schemes (showing PAPR v/s CCDF) if the DCT is applied only at companding

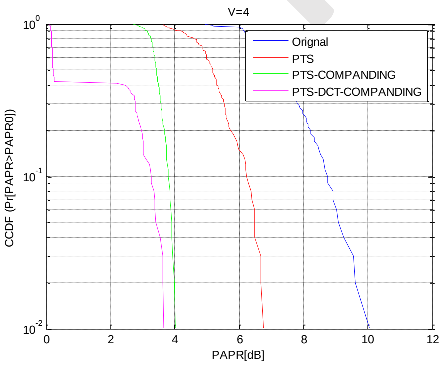

Figure 6: Comparison of different schemes (showing PAPR v/s CCDF) if the DCT is applied on both PTS and companding

IV. Conclusion

Orthogonal frequency division multiplexing (OFDM) signals have a generic problem of high peak to average power ratio (PAPR) which is defined as the ratio of the peak power to the average power of the OFDM signal. The drawback of the high PAPR is that the dynamic range of the power amplifiers (PA) & digital-to-analog (D/A) converters required during the transmission and reception of the signal is higher. As a result, the total cost of the transceiver increases, with reduced efficiency. After analyzing some specific algorithms, we propose a novel algorithm by combining the Partial transmit sequence (PTS), Companding and Discrete Cosine Transform techniques which includes an idea of the PAPR constraint, along with the implementation and analysis for PAPR reduction of the OFDM signals. This algorithm is implemented and tested in the OFDM transceiver designed using MATLAB. The simulation result conclude that the output obtained by hybrid technique reduces the PAPR drastically rather than other techniques.

Reference

[1] David Tse, University of California, Berkeley, “Fundamentals of Wireless Communication”, September 10, 2004.

[2] C.Y. Soo, J. Kim, W.Y. Yang, and C.G. Kang, “MIMO-OFDM wireless communications with MATLAB”, John Wiley & Sons, 2010.

[3] T. S. Rappaport, “Wireless Communications, Principles and Practice”, New Jersey: Prentice Hall, 1996.

[4] A.G. Armada, “Understanding the effects of phase noise in orthogonal frequency division multiplexing (OFDM)”, IEEE Transactions on Broadcasting, Vol. 47, pp. 153-159, Jun 2001.

[5] A. D. S. Jayalath, “OFDM for Wireless Broadband Communications (Peak Power Reduction, Spectrum and Coding)”, Science and Software Engineering Melbourne: in School of Computer Monash University, pp. 257, 2002.

[6] J. H. Wen, G.R. Lee and C.Y. Yang, “The PAPR Reduction in OFDM System with the Help of Signal Mapping Scheme”, International Journal of Applied Science and Engineering, Vol. 5, Issue 1, pp. 75-80, 2007.

[7] H.Y. Sakran, M. Shokair and A.A. Elazm, “An Efficient Technique for Reducing PAPR Of OFDM System In The Presence Of Nonlinear High Power Amplifier”, Progress In Electromagnetics Research, Vol. 2, pp. 233–241, 2008.

[8] H.Y. Sakran, M. Shokairand A.A. Elazm, “Combined Interleaving and Companding for PAPR Reduction in OFDM Systems”, Progress In Electromagnetics Research, Vol. 6, pp. 67–78, 2009.

[9] V.B. Malode and B.P. Patil, “PAPR Reduction Using Modified Selective Mapping Technique”, IJANA, Vol. 2, Issue: 02, pp 626-630, 2010.

IJDACR International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 6, January 2017)

[10] P. S. Varahram and B.Mohd. Ali, "Partial transmit sequence scheme with new phase sequence for PAPR reduction in OFDM systems", IEEE Transactions on Consumer Electronics, ISSN: 0098-3063, Vol. 57, Issue 2, pp. 366-371, May 2011.
[11] M. Pant and D. Nitnawwre, "Performance Improvement of OFDM System Using PAPR Reduction", International Journal of Advanced Research in Computer Science and Software Engineering (IJARCSSE), ISSN: 2277 128X, Vol. 2, Issue 5, May 2012.
[12] R. Baranwal, A. Kumar and C. K. Shukla, "Effect of Different Modulation on PAPR and Its Reduction", International Journal of Computer Science & Engineering Technology (IJCSET), Vol. 3, No. 8 August 2012.
[13] Gamal Mabrouk Abdel–Hamid, Sahar Abdel-Rahman, "Performance Improvement of MIMO-OFDM Wireless Systems using PAPR Reduction Techniques", International Journal of Computer Applications, Volume 53– No.18, September 2012.
[14] Mishra, Himanshu Bhusan, Madhusmita Mishra, and Sarat Kumar Patra. "Selected mapping based PAPR reduction in WiMAX without sending the side information." In Recent Advances in Information Technology (RAIT), 2012 1st International Conference on, pp. 182-184. IEEE, 2012.
[15] I. Mohd. Hussain, "Low Complexity Partial SLM Technique for PAPR Reduction in OFDM Transmitters", International Journal on Electrical Engineering and Informatics (IJEEI) – Vol. 5, No. 1, March 2013.
[16] SrinuPyla, K. Padma Raju, N. Balasubrahmanyam, "PAPR reduction in OFDM systems using pts and various modulation schemes", IEEE, 2013.
[17] R.W. Bauml, R.F.H. Fischer and J.B. Huber, "Reducing the Peak to Average Power Ratio of Multicarrier Modulation by Selective Mapping", IEEE Electronics Letters, vol.32, no.22, pp. 2056-2057, Oct. 1996.
[18] H.Y. Sakran, M. Shokairand A.A. Elazm, "Combined Interleaving and Companding for PAPR Reduction in OFDM Systems", Progress In Electromagnetics Research, Vol. 6, pp. 67–78, 2009.