Harmonic Suppression Technique using AIA for MPA

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Abstract---This thesis work presents a new harmonic suppression technique for microstrip patch antennas. Harmonic suppression in active integrated antennas is known as an effective method to improve the efficiency of amplifiers in transmitter side. In the proposed design, the antenna works as the radiating element and, at the same time, as the tuning load for the amplifier circuit that is directly matched to the antenna. The proposed active antenna architecture is easy to fabricate and is symmetric, so it can be conveniently mass-produced and designed to have circular polarization, which is preferred in many applications such as satellite communications. The antenna simulations were performed using High Frequency System Simulator (HFSS). Based on the success in the single element active antenna design, the thesis also presents a feasibility of applying the active integrated antenna in array configuration, in particular, in scanning array design to yield a low-profile, low-cost alternative to the parabolic atenna transmitter of satellite communication systems.

Keyword: - Antenna, AIA, Axial Ratio, Harmonic Suppression

I. INTRODUCTION TO ANTENNA

In the 1890s, there were only a few antennas in the world. These rudimentary devices were primarily a part of experiments that demonstrated the transmission of electromagnetic waves. By World War II, antennas had become so ubiquitous that their use had transformed the lives of the average person via radio and television reception. The number of antennas in the United States was on the order of one per household, representing growth rivaling the auto industry during the same period. A rough outline of some major antennas and their discovery/fabrication dates are listed:

- Yagi-Uda Antenna, 1920s
- Horn antennas, 1939. Interesting, the early antenna literature discussed waveguides as "hollow metal pipes".
- Antenna Arrays, 1940s
- Parabolic Reflectors, early 1950s
- Patch Antennas, 1970s.
- PIFA, 1980s.

Current research on antennas involves metamaterials (materials that have engineered dielectric and magnetic constants, that can be simultaneously negative, allowing for interesting properties like a negative index of refraction). Other research focuses on making antennas smaller, particularly in communications for personal wireless communication devices (e.g. cell phones). A lot of work is being performed on numerical modeling of antennas, so that their properties can be predicted before they are built and tested.

A. Gain And Directivity

The gain of an antenna is the radiation intensity in a given direction divided by the radiation intensity that would be obtained if the antenna radiated all of the power delivered equally to all directions. The definition of gain requires the concept of an isotropic radiator; that is, one that radiates the same power in all directions. An isotropic antenna, however, is just a concept, because all practical antennas must have some directional properties. Nevertheless, the isotropic antenna is very important as a reference. It has a gain of unity (g = 1 or G = 0 dB) in all directions, since all of the power delivered to it is radiated equally well in all directions.

Although the isotopes are a fundamental reference for antenna gain, another commonly used reference is the dipole. In this case the gain of an ideal (lossless) half wavelength dipole is used. Its gain is 1.64 (G = 2.15 dB) relative to an isotropic radiator. The gain of an antenna is usually expressed in decibels (dB). When the gain is referenced to the isotropic radiator, the units are expressed as dBi; but when referenced to the half-wave dipole, the units are expressed as dBi. The relationship between these units is

$$G_{dBd}G_{dBd} = G_{dBi}G_{dBi} - 2.15dBi \dots\dots\dots\dots\dots\dots\dots\dots\dots.. (1)$$

Directivity is the same as gain, but with one difference. It does not include the effects of power lost (inefficiency) in the antenna. If an antenna were lossless (100 % efficient), then the gain and directivity (in a given direction) would be the same.

$$D = \frac{F_{max}}{F_o} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \dots\dots \ (2)$$

F_{max} =maximum radiated energy
F_o =isotropic radiator radiated energy

B. Input Impedance

There are three different kinds of impedance relevant to antennas. One is the terminal impedance of the antenna, another is the characteristic impedance of a transmission line, and the third is wave impedance. Terminal impedance is defined as the ratio of voltage to current at the connections of the antenna (the point where the transmission line is connected). The complex form of Ohm's law defines impedance as the ratio of voltage across a device to the current flowing through it.

The most efficient coupling of energy between an antenna and its transmission line occurs when the characteristic impedance of the transmission line and the terminal impedance of the antenna are the same and have no reactive component. When this is the case, the antenna is considered to be matched to the line. Matching usually requires that the antenna be designed so that it has a terminal impedance of about 50 ohms or 75 ohms to match the common values of available coaxial cable.

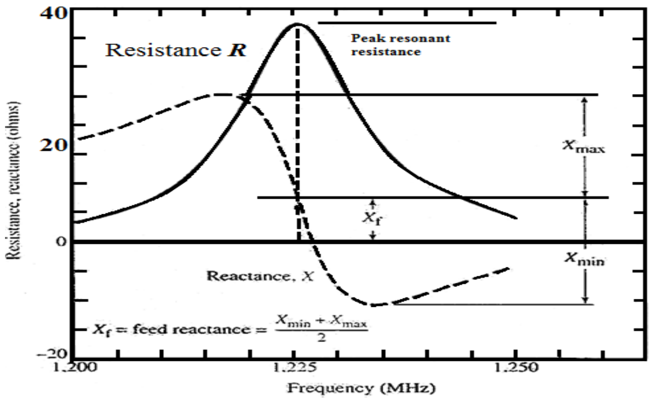

Fig. 1: Typical variation of resistance and reactance of rectangular Microstrip antenna versus frequency

The input impedance of patch antenna is in general complex and it includes resonant and non-resonant part. Both real and imaginary parts of the impedance vary as a function of frequency. Ideally, both the resistance and reactance exhibit symmetry about the resonant frequency as shown in Figure 2.1. Typically, the feed reactance is very small, compared to the resonant resistance for thin substrates.

C. Voltage Standing Wave Ratio

The standing wave ratio (SWR), also known as the voltage standing wave ratio (VSWR), is not strictly an antenna characteristic, but is used to describe the performance of an antenna when attached to a transmission line. It is a measure of how well the antenna terminal impedance is matched to the characteristic impedance of the transmission line. Specifically, the VSWR is the ratio of the maximum to the minimum RF voltage along the transmission line. The maxima and minima along the lines are caused by partial reinforcement and cancellation of a forward moving RF signal on the transmission line and its reflection from the antenna terminals.

If the antenna terminal impedance exhibits no reactive (imaginary) part and the resistive (real) part is equal to the characteristic impedance of the transmission line, then the antenna and transmission line are said to be matched. It indicates that none of the RF signal sent to the antenna will be reflected at its terminals. There is no standing wave on the transmission line and the VSWR has a value of one. However, if the antenna and transmission line are not matched, then some fraction of the RF signal sent to the antenna is reflected back along the transmission line. This causes a standing wave, characterized by maxima and minima, to exist on the line. In this case, the VSWR has a value greater than one. The VSWR is easily measured with a device and VSWR of 1.5 is considered excellent, while values of 1.5 to 2.0 is considered good, and values higher than 2.0 may be unacceptable.

Most wireless system operates at 50 Ohm impedance. Hence the antenna must be designed with an impedance as close to 50 ohm as possible. A VSWR of 1 indicate an antenna impedance of exactly 50 ohms. Mostly, the ratio of VSWR≥1.5:1 is needed for antenna functional. Table 2.1 shows several VSWR value compare to reflection coefficient [S11] value. Value of VSWR 2:1 ([S11] = -9.5 dB)shows 90% of power reflected. While for VSWR 3:1 ([S11] = -6dB), shows 75 % power is reflected. A good antenna to operate is within 1≤VSWR≤2.

GOOD

VSWR	Return Loss [S11]
1.01	-46.1
1.05	-32.3
1.10	-26.4
1.20	-20.8
1.30	-17.7
1.40	-15.6
1.50	-14.0
1.75	-11.3
2.00	-9.5
2.50	-7.4
3.01	-6.0

NOT GOOD

D. Bandwidth

The bandwidth of an antenna is defined as the range of frequency within the performance of the antenna. In other words, characteristics of antenna (gain, radiation pattern, terminal impedance) have acceptable values within the bandwidth limits. For most antennas, gain and radiation pattern do not change as rapidly with frequency as the terminal impedance does. Since the transmission line characteristic impedance hardly changes with frequency, VSWR is a useful, practical way to describe the effects of terminal impedance and to specify an antenna's bandwidth. For broadband antennas, the bandwidth is usually expressed as the ratio of the upper to lower frequencies of acceptable operation. However, for narrowband antennas, the bandwidth is expressed as a percentage of the bandwidth.

$$narrow\ band\%\quad BW = \frac{f_h(upper\ freq.) - f_l(lower\ freq.)}{f_o(operating\ freq.)} \ldots\ldots\ldots\ldots\ldots (3)$$

$$broad\ band\%\quad BW = \frac{f_h(upper\ freq.)}{f_o(resonant\ freq.)} \ldots\ldots\ldots\ldots\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (4)$$

II. Literature Review

After referring various papers related to reduce the harmonics of microstrip patch antenna. Getting awared from various papers , I decided to suppress 2nd and 3rd harmonics of the patch antenna with the operating frequency of 2.4 Ghz.

H. Kim and Y. J. Yoon, Compact micro strip-fed meander slot antenna for harmonic suppression," Electronics Letters, vol. 39, no. 10, pp. 762-763, May 2003.[1]

A novel compact micro strip-fed meander slot antenna is proposed to achieve suppression of harmonics and miniaturisation of the antenna. To obtain these characteristics, a meander-type slot radiator and U-shaped conductor line connected with the ground plane are applied. The real parts of the measured input impedance at the second- and third-harmonic frequencies are nearly zero. In the measured radiation patterns in E- and H-plane, the second- and third-harmonic suppressions are observed to be approximately less than -30 dB.

S. Kwon, B. M. Lee, Y. J. Yoon, W. Y. Song, and J.-G. Yook, A harmonic suppression antenna for an active integrated antenna," Microwave and Wireless Components Letters, IEEE, vol. 13, no. 2, pp. 54-56, Feb. 2003.[2]

In this letter, a defected ground structure (DGS) is applied to design a compact micro strip rat-race hybrid coupler. The proposed structure can achieve both a significant reduction of size and harmonic signal. By embedding the DGS section, it is observed that the resonant frequency of the hybrid coupler is significantly lowered, which can lead to a large amount of size reduction for a fixed frequency operation. Besides, the third harmonic signal is suppressed to -30 dB with respect to a conventional rat-race hybrid coupler. In this case, the measured insertion loss is comparable to that of a conventional hybrid coupler.

L. Chiu, T. Yum, C. Chin, Q. Xue, and C. Chan, High-efficiency class-B push-pull amplifying array for microwave transmitting front end," Microwaves, Antennas and Propagation, IEE Proceedings, vol. 153, no. 1, pp. 25-28, Feb. 2006.[3]

The authors present a novel push-pull amplifying array using quadruple antenna-patch couplers and dual-feed antennas. It exploits the advantages of both class-B push-pull amplifiers and active integrated antennas (AIAs), resulting in a high-efficiency, linear and yet compact design. A state-of-the-art heterojunction FET power amplifier of 50% peak power-added efficiency (PAE) is achieved at 10 GHz. A three-element array prototype was successfully built, achieving a peak antenna gain of 19.6 dBi. This is 5.7 and 10.4 dB better than amplifying arrays using the antenna-patch coupler approach and the conventional parallel feeding network, respectively.

C. I. Lee, W. C. Lin, Y. T. Lin, and Y. T. Lee, A novel H-shaped slotcoupled antenna for the integration of poweramplifer," in Progress In electromagnetics Research Symposium Proceedings, pp. 385-389, July 2010.[4]

In this work, they propose a new technique for comprehensive scanner matching to fundamentally improve scanner productivity in a Giga fab. The proposal covers matching solutions for both CD and overlay fingerprints among scanners. CD matching strategy has three main components. The first part is to apply model-based scanner tuning for scanner optics matching. The second part is to apply hotplate-tuning mechanism for within-wafer CD uniformity improvement. The third part is to achieve focal plane control with a novel focus metrology method. Overlay control and matching are achieved with periodic inter-field and intra-field high order process correction with respect to the chosen baseline of overlay fingerprint for each scanner. Together with the existent inline automatic process control infrastructure, which suppresses the residual process-induced CD and overlay variations, a holistic scanner matching solution can be implemented in the fab for productivity and yield enhancements. Convincing proof data is provided in this paper to demonstrate the feasibility of our approach.

Y. Sung, M. Kim, and Y. Kim, "Harmonics reduction with defected ground structure for a microstrip patch antenna," Antennas and Wireless Propagation Letters, IEEE,vol. 2, no. 1, pp. 111-113, Dec. 2003.[5]

A microstrip patch antenna using a defected ground structure (DGS) to suppress higher order harmonics is presented. An H-shaped defect on the ground plane with only one or more unit lattices has been utilized and yielded band stop characteristics. Compared with a conventional microstrip patch antenna without the DGS unit cell, the radiated power of the DGS patch antenna at harmonic frequencies has been drastically decreased.[5]

D. Goshi, K. Leong, and T. Itoh, "Electronics insertion into printed antennas," inAntennas and Propagation, 2006. EuCAP 2006. First European Conference, pp. 1-4,Nov. 2006.[6]

Although antennas are followed by RF front ends made of electronic components in most radio communication and radar systems, they are typically separated in design and fabrication. This paper provides some effort to unify these two entities to create new avenues for efficient system design. The paper provides examples in two categories; active integrated antennas, and retrodirective systems. In the first category, both antennas and electronic devices are benefiting from each other by placing the device within or in close proximity of the antenna. The latter typically provides circuit functions in addition to radiation capability. The second category is an interesting system capable of providing special radiation properties from the system in which antennas and devices work together.

S. F. Ooi, S. K. Lee, A. Sambell, E. Korolkiewicz, and S. Scott, "A new approachto the design of a compact high e_ciency active integrated antenna," Microwave and Optical Technology Letters, vol. 50, no. 3, pp. 585-589, Mar. 2008[7].

An explicit and computationally efficient coupling impedance formula for the coupling between two perimeter ports on a perpendicular side of a right-angled isosceles triangular patch microstrip segment is derived. Based on coplanar circuit analysis an initial impedance formula is obtained in terms of a single and a double infinite series expression. Application of closed forms for the series reduces the single series to a closed form, and, the double series reduces to a single series. The new computationally efficient coupling formula is verified by comparison with simulation based on full wave analysis, and, practical measurement.

H. Kim and Y. J. Yoon, "Microstrip-fed slot antennas with suppressed harmonics,"Antennas and Propagation, IEEE Transactions, vol. 53, no. 9, pp. 2809-2817, Sept.2005.[8]

In this paper, microstrip-fed slot antennas with suppressed harmonics are proposed. To obtain this operation, conductor lines connected with ground plane are inserted in slot antennas. To verify the validation of the proposed antennas, the equivalent circuit analysis is presented. Also, the miniaturization and bandwidth enhancement of the antenna for various applications are achieved and analyzed through parameter study. From the measured return losses, input impedances, and radiation patterns, it is shown that the proposed antennas offer excellent harmonic suppression characteristic in harmonic bandwidth including the second and third harmonic frequencies.

III. CONCLUSION

By studying different papers on harmonic reduction technique ,I have implemented and observed, the design of MPA(microstrip patch antenna) and AIA(Active integrated Amplifier) on simulation based results using HFSS(High Frequency Simulation Software),for 2.4Ghz as an operating frequency,I have got the axial ratio one for both the polarization linear as well as circular.

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[7] S. F. Ooi, S. K. Lee, A. Sambell, E. Korolkiewicz, and S. Scott, "A new approachto the design of a compact high e_ciency active integrated antenna," Microwave and Optical Technology Letters, vol. 50, no. 3, pp. 585-589, Mar. 2008[7].

