Small Antennas for the Reception of Future Mobile Television Services

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ABSTRACT: Many mobile service providers are planning to introduce digital television services over the next few years. The reception of UHF TV signals on mobile user devices will require new electrically small antennas capable of operating over a wide frequency band. This paper describes the problems to be overcome and proposes solutions for further development.

INTRODUCTION

Over the last decade antenna designers have become very familiar with the problems associated with the development of efficient broadband antennas for use in the frequency bands currently allocated world-wide for mobile phone services. Especially in the lower frequency bands (824–960MHz) it is well recognized that radiation takes place from both the antenna structure and the groundplane of the handset [1]. Using available techniques it is possible to provide minimum radiation efficiencies of around 50% across the low bands, but this target is often not achieved when the platform is too small (<~80mm long), when space constraints mean that inadequate space can be provided for the antenna, or when surrounding components couple RF energy from the antenna and cause the loss of RF power into other circuits on the platform.

By comparison with the total relative bandwidth of the mobile radio bands (16% for both low bands), the frequency band used for UHF TV services (470MHz–860MHz) has a much larger relative bandwidth (83%). The impact of this on antenna design is considerable; both the platform and the potential antenna structures are electrically smaller than for the mobile radio bands, yet the required bandwidth is far larger.

The link budget for mobile TV strongly influences the cost of providing effective coverage [2], so the use of antennas with inadequate gain has consequences which may make the service uneconomic in some areas. In [3] it is demonstrated that it is possible to meet a gain target of -10dBi at 470MHz rising to -7dBi at 700MHz, but the reported results indicate the gain at many frequencies was at least 3dB below what could have been achieved by optimal tuning. (Many user devices will provide both DVB-H and DVB-T reception, so they will also need to cover frequencies up to 860MHz.)

A useful improvement in antenna gain can be provided by using an antenna tuned to the required signal frequency, as the bandwidth of a digital TV signal (7.8MHz) occupies only a small fraction of the total available frequency band. The use of automatically-tuned antenna matching networks is well known in other applications, particularly in military applications in the HF band. The most obvious strategy for tuning a transmitting antenna is to place a dual directional coupler at the input to the matching network and to adjust the variable matching components so the input impedance reaches some desired value, typically with the required forward power and minimal reflected power. In the case of a receiving antenna, tuning is less easy because it is not possible to base a tuning algorithm on an impedance measurement and a search for the correctly tuned position may be difficult if the initial chosen position provides a very poor impedance match – in this condition sweeping either tuning component across its whole range of values may still produce no detectable received signal.

In the case of mobile TV reception an additional problem is posed by the fact that the reception frequency at any arbitrary location of the receiver may not be known to the equipment, so optimizing antenna tuning must be combined with a search for a usable signal. Ideally we would like a device in which varying the value of a single variable component matches the antenna at any wanted frequency, allowing the band to be scanned for a signal, but this is difficult to achieve for a small antenna over a wide frequency range. In the discussion which follows, we examine the impedance behavior of two different antenna designs and review strategies and hardware for tuning them.

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ANTENNA DESIGN EXAMPLES

A Dielectric-Excited Antenna with a Single Tuning Component

Initial work began from design starting points of a PIFA or a dielectric-excited antenna. If a PIFA is provided with a tuning capacitor connected across its open end it is easy to change its resonant frequency, but when tuned over a wide frequency band the impedance at resonance varies greatly from a chosen nominal value (not necessarily 50 ohms). A series of experiments with various forms of antenna led to the design of a dielectric-excited inverted-F antenna, based on the design in [4], which gave more promising results especially when the tuning capacitance was placed part-way along the meandered top conductor. This approach led to the design shown in Fig. 1, in which a varactor diode was used to tune the antenna, the bias voltage being fed through an isolating inductor. This design still exhibits considerable variation in its input impedance at resonance. With the tuning capacitor at its minimum value the antenna must resonate at the upper band edge; other dimensions must then be chosen to provide the optimum matching at 470MHz, the input impedance at the upper end of the band being still matched well enough to provide the required efficiency.

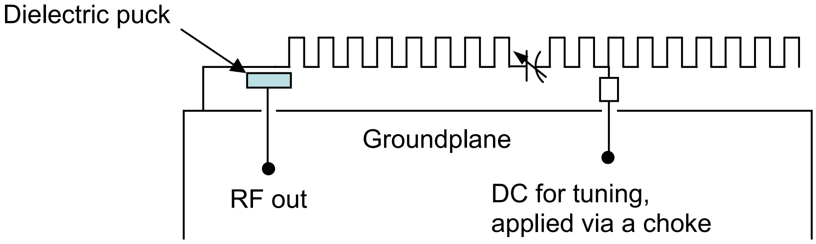

Fig. 1: Arrangement of the single-tuned dielectric-excited antenna. The configuration of the meander is simplified for clarity.

An inverted-F Antenna with Double Tuning

It is a well known feature of the inverted-F antenna that the input resistance at resonance can be controlled by selection of the point at which the input line is connected to the top conductor relative to the short-circuited end of the conductor. The real part of the input impedance at resonance rises as the feed point moves away from the grounding point. We can regard the effect as resulting from increasing the coupling between the current circulating between the input and ground and the current flowing in the remainder of the structure. This is more fully described in [5].

The second antenna design was based on a classical inverted-F, but in addition to a variable capacitance across the open end of the top loading conductor, a second variable capacitance was placed in series with the usual fixed connection to ground. These two capacitances control the resonant frequency and the coupling factor respectively; although there is some interaction between these two functions they are substantially independent. The arrangement should allow an accurate impedance match to be obtained at any frequency across the operating band under the control of a simple tuning algorithm based on the RF signal level detected by the receiver. In practice this would probably be augmented by a lookup table providing starting values at different frequencies.

This planar design was constructed with dimensions 15mm x 50mm. It was possible to match the antenna at any frequency from 860MHz down to less than 200MHz, although with the chosen dimensions the efficiency at the lower frequencies became very small. By using eight values for C1 and two values for C2 the antenna could be well matched between 470MHz and 860MHz with a minimum useful bandwidth of 8MHz. The measured efficiencies of the antenna when mounted on a groundplane simulating a mobile Internet device (MID)are shown in Fig 3. The same design was constructed on two smaller platforms to investigate the influence of groundplane dimensions on efficiency with the results shown in Figs 4a and 4b.

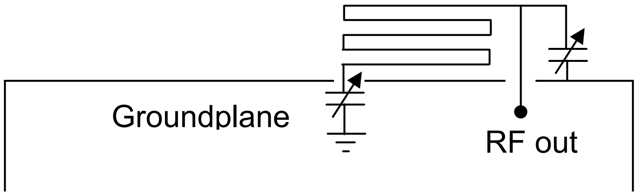

Fig 2: Inverted-F antenna with broadband double tuning arrangement [6]

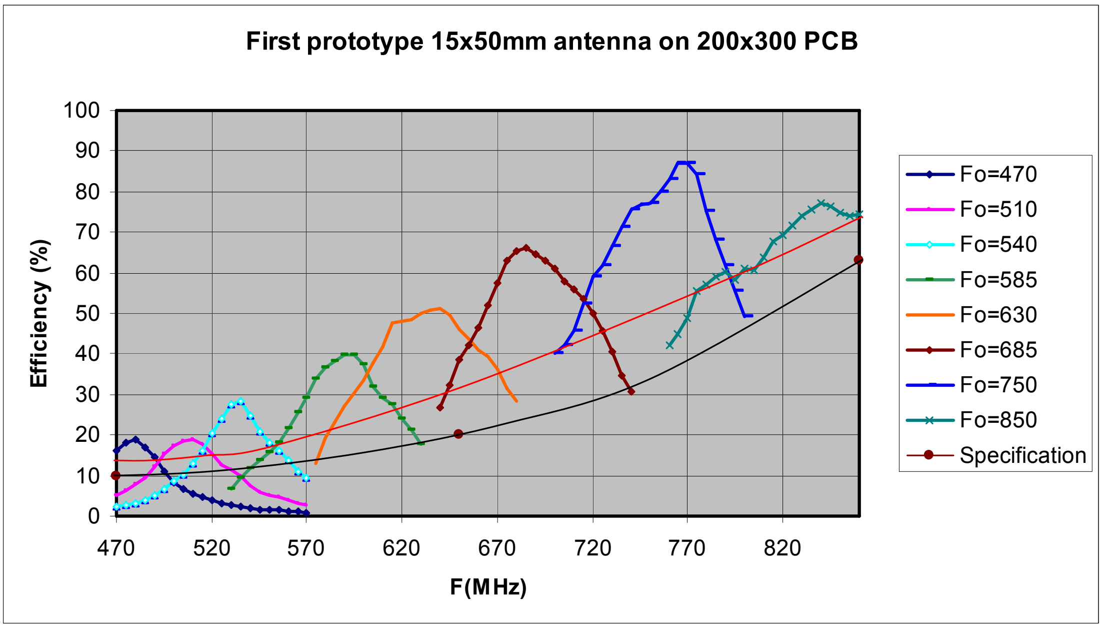

Fig. 3: Efficiency v frequency measured on a prototype double-tuned inverted-F antenna, 50mm x 15mm (w x h) on a 200mm x 300mm groundplane. Eight values of tuning capacitance were used in this experiment. The lower solid line indicates the target specification while the upper line indicates the minimum efficiencies achieved.

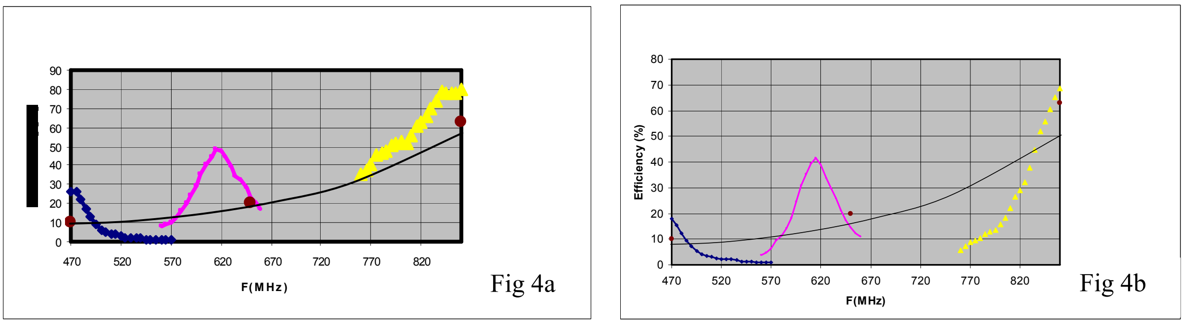

Fig 4a

Fig 4b

Fig. 4a,b: Efficiency v frequency measured at the bottom, middle and top of the band for groundplanes 200mm x 300mm and 100mm x 200mm

different in this respect because one requires a series capacitor while the other uses two capacitors to ground. Factors of interest include not only the Q-factor of the capacitors, but also the range of capacitance available, the minimum capacitance obtainable, the complexity and likely RF losses in the control or bias circuits, power consumption and cost.

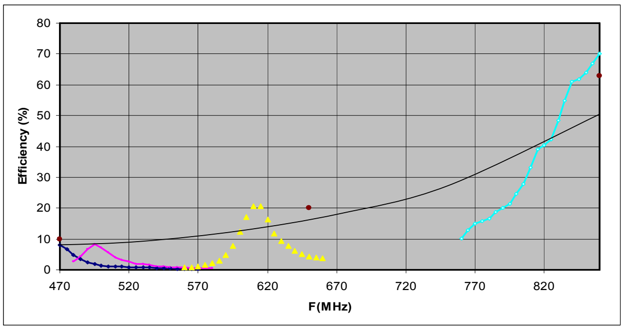

Fig 4c: Efficiency v frequency measured at the bottom, middle and top of the band on a groundplane 120mm x 70mm

Unfortunately, the maximum tuning capacitance is needed to tune the bottom end of the band of interest, when the bandwidth is minimum and the sensitivity of the device to tuning component losses is greatest. Varactor diodes tend to have their lowest Q at maximum capacitance, so they may not prove to be a good choice.

The DVB-H Environment

Most existing receiver designs for DVB-H employ external telescopic whip antennas but there is pressure from equipment designers for more user-friendly internal antennas. The cost of broadcast infrastructure is sensitive to receiver performance so it is essential that the mobile antenna delivers as much signal as possible to the receiver. It is highly desirable that receivers operate with at least 2-branch diversity – yet this adds cost and results in more space being required for antennas. The practical situation adds a further twist to what is already a challenging situation: when moved from the service area of one transmitter to that of another the receiver must discover the channels that are in use. Domestic DVB-T receivers carry out a systematic search, but this is a slow process, taking two minutes, even when the receiver is provided with an input signal much larger than expected for a mobile UE. In the mobile environment there is a risk that the antenna cannot be tuned during a channel-scan because there is insufficient receiver output to control the process, yet at the same time the maladjustment of tuning controls may be what has resulted in no signal being detected. An antenna relying on tuning to achieve optimum output must be capable of reliable control using a simple look-up table and any secondary tuning process must be under the control of a simple and robust algorithm. The avoidance of frequent channel scans is a very significant benefit of the use of a single frequency network (SFN) for DVB-H services.

CONCLUSION

The design of optimal small antennas for DVB-H services to mobile platforms is a major technical challenge. The use of narrow-band designs tuned to the required working frequency offers more gain than broadband designs which must of necessity be compromises in view of their small electrical dimensions.

ACKNOWLEDGEMENTS

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