Broadband-Multiband Antennas Enabling Capacity & Security for Mobile Wireless 5G and Beyond

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***Abstract* – A solution for antenna needs in upcoming 5G mobile wireless is presented. It is based on employment of broadband multiband antennas, including wide-scan mmWave phased arrays. This new approach is indispensable not only in dealing with the high capacity and data rates, but also in enabling physical-layer security in the cyberspace, for 5G and beyond. The discussions are focused on smartphones, where the design is by far more complex, difficult, and costly due to their small size. A feasibility study has been performed by breadboard experimentation; the results so far are highly promising.**

***Index Terms* — 5G mobile wireless, broadband multiband antenna and phased array, cyber security, physical layer security, smartphone.**

1. Antenna Requirements for 5G mobile wireless

Frequency bands employed in smartphones expanded rapidly after the debut of *i*phone in 2007. Today, numerous bands ranging from 614 MHz to 43.5 GHz are on the drawing boards for the upcoming global 5G mobile wireless [1]. Table I shows the requirements for 5G antennas.

Table I is subject to changes and updates due to technical difficulties and changes in regulatory status. Also, frequency spectra plans for 5G mobile wireless differ somewhat from country to country. For example, US FCC dismantled Net Neutrality regulations in late 2017, thus removed regulatory barrier, allowing more and wider frequency bands in broadband internet.

In the consumer market, hacking and security failures in cyberspace have rapidly risen exponentially since 2013. *Today, security and anti-spoofing are more important than performance to users, as evidenced by an ad in December 2017 by market leader Samsung [2].*

TABLE I
Antenna Requirements in Upcoming 5G Mobile Wireless.

System or plan	Freq. (MHz)	Pol	Gain	Pattern	Sat/Ter	Tx/Rx
mMTC	614-1000	LP	Low	Omni	Terrestr	**Tx/Rx**
3GPP and LTE	@ 1700, 2000, 2500	LP	Low	Omni	Terrestr	**Tx/Rx**
GNSS	1210-1610	**RHCP**	Low	Hemi-spheri	Satellite	**Rx**
MT & others	3300-4200	LP	Low	Omni	Terrestr	**Tx/Rx**
Japan/China	4400-5000	**LP**	Low	Omni	Terrestr	**Tx/Rx**
mmWave	24250-43500	LP	High	Beam-scan	Terrestr	**Tx/Rx**

Requirements on GNSS antenna for operations with direct GNSS satellite coverage discussed in [3] must be updated to meet today's operating environments severely crowded by jamming and spoofing for consumers [4]. 5G's requirement of mmWave phased arrays with beam scan for full spatial coverage was astonishing—not only for its expansion into mmWave frequencies but also for its bold venture into the complex and costly beam-scan phased arrays [5]. It was then obvious that broadband antenna is indispensable in meeting both capacity and security needs in 5G and beyond, a path traveled by the Aerospace & Defense Industry (DAI) [6]-[8].

2. The Broadband-Multiband Approach in Defense & Aerospace Industry (DAI)

Evidently the cellphone industry has begun to follow the footsteps of DAI as it promoted "Defense-grade security for an open world" in mobile security in December 2017 [2]. In 1980 US military planners started R&D in *broadband multiband antennas and phased arrays as they are the necessary and enabling foundations indispensable for performance and security in wireless communications*.

Under SpeakEasy and later JTRS, greatly benefited by the technology and cost-reduction borne out of the global boom of smartphones, the 30-year R&D in the US led to production of broadband-multiband military smartphone handsets in DAI. For the first 100,000 units fielded worldwide, the cost is estimated to be over $30,000 per unit.

The newest model of Army AN/PRC-152A wideband network handheld handset can cover six functions ranging from 30 MHz to 2000 MHz, in a contiguous way. A satisfactory solution for the needed broadband multiband antennas covering all bands and suitable for field operations has been demonstrated [8].

3. The Breadboard for Feasibility Study

An initial study on the feasibility of this new approach is conducted with breadboard experimentation. Fig. 1 shows the proposed antenna arrangement on a smartphone, consistent with the concept in [1]. The details are as follows.

(1) For frequencies below 6 GHz

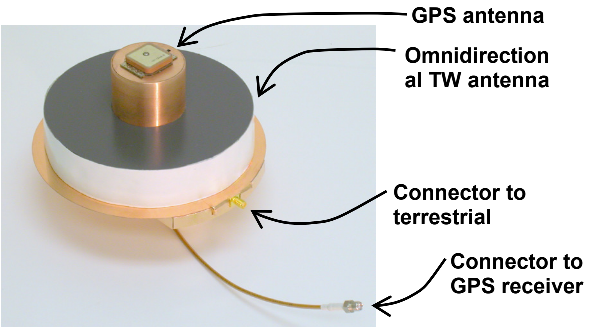
For frequencies below 6 GHz, the antenna technology is based on three-dimensional (3D) Traveling-Wave Antenna (TWA) technology. Its application to automobile was first published in ISAP 2011 [9] and later for a more advanced model with more details in [10] as shown in Fig. 2.

Fig. 1. Proposed antenna arrangement on a smartphone.

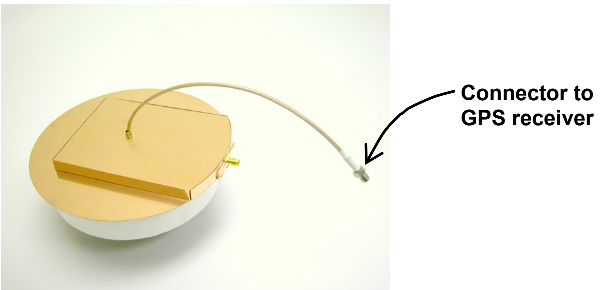
Implementation of TWA as a body-wearable device for Army wideband network handheld handsets has been successfully demonstrated [8]. For 5G the 3D TWA will be shrunk to about 1/5. Fortunately, like other cellphone antennas, for lower frequencies it serves essentially as a launcher; the body of the cellphone is the actual radiator.

(2) For frequencies above 6 GHz

For frequencies above 6 GHz, the enabling antenna technology is three-dimensional (3D) Traveling-Wave Antenna Array (TWAA) discussed in [6]-[7]. True Time Delay (TTD) Analog Beam Forming (ABF) is based on a Rotman-lens technology developed in 1992 for a linear array of flared-notch elements, as shown in Fig. 3. It was carried out by this author and his colleagues at Georgia Tech. The Rotman lens was dielectrically loaded (dielectric constant =10) to reduce size. *The measured radiation patterns over 1.5-6.0 GHz showed near 4:1 bandwidth with maximum beam scan of ±60°*. The work was documented in an October 1992 report but not published. The Rotman lens for 5G will be designed to match TWAA and have an encapsulated coplanar waveguide configuration.



(a) Perspective top view



(b) Perspective bottom view

Fig. 2. Integrated multifunction antenna in perspective (a) top view, and (b) bottom view.

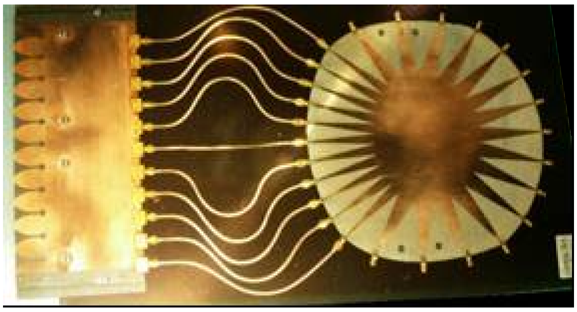


Fig. 3. Flared-notch array with TTD ABF developed 1993.

4. Results Are Highly Promising

A feasibility study on the proposed antenna solution for 5G and beyond shows that is highly promising, mainly due to the maturity of TWA and TWAA technologies, which have achieved estimated TRL-7 and MRL-7. There are some uncertainties on the space available and gain requirement in [1] even though they apparently reflect the consensus of four leading cellphone manufacturers: Samsung, Ericsson, Nokia, and Huawei.

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