

SOFTWARE DEFINED RADIO, SDR



EE568 – SOFTWARE DEFINED RADIO

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OUTLINE

➤ INTRODUCTION BACKGROUND

- HISTORY – DEFINITION
- SDR FORUM
- SDR LEVELS

➤ HARDWARE IMPLEMENTATION

- SDR ARCHITECTURE
 - ANALOG RF FRONT-END
- GENERATION OF PROGRAMMABLE FREQUENCIES
 - DIGITAL PLL SYNTHESIS
 - DDS
- BASEBAND PROCESSING
 - DSP BOARDS/FPGAS
- MULTIMODE ANTENNAS
- SMART ANTENNAS

➤ SDR USAGE/BENEFITS

- EASE OF SW UPDATES

➤ SDR FEATURES/APPLICATIONS

- FM
- MULTIMODE CELLULAR
- GPS

➤ FUTURE WIRELESS

- 'UNIVERSAL' HANDSET

➤ SUMMARY

WIRELESS MODULE SCALABILITY

- **MOST MOBILE DEVICES ARE EQUIPPED WITH WI-FI, MOBILE CELLULAR (CDMA/GSM/UMTS/LTE), GPS; ALL IMPLEMENTED USING DIFFERENT STANDARDS AND EACH HAVING ITS OWN 'DEDICATED' TRANSCEIVER CHIP SET**
- **DIFFERENT STANDARDS AND PROTOCOLS ARE REALIZED BY COMBINING ALL THESE TRANSCEIVER CHIP SETS ONTO A DEVICE**
- **IN RECENT YEARS, INTEGRATING ALL THESE CHIPS INTO A SMALL DEVICE PRESENTED A CHALLENGE TO THE R&D COMMUNITY**
- **SOLVING THIS ENTAILED NEW AND INNOVATIVE WAYS IN DEVELOPING A COMPLETELY FLEXIBLE RADIO**

WIRELESS MODULE SCALABILITY CONT'D

- **IN ADOPTING SDR, ALL THE AFOREMENTIONED FUNCTIONALITIES ARE REALIZED USING AN SDR TRANSCEIVER COUPLED WITH AN RF BASEBAND MODULE I.E. DIGITAL FILTERING, MODULATION, DEMODULATION, COMPRESSION ARE ALL CARRIED OUT AND PROCESSED BY A DSP/FPGA**
- **TRADEOFF EXISTS IN TERMS OF APPLICATION VARIETY FOR THE USER AND HARDWARE SIZE MINIMIZATION**

SDR HISTORY - DEFINITION

- **IN 1991, JOE MITOLA COINED SOFTWARE RADIO, SDR, TO IMPLY A RADIO THAT CAN BE REPROGRAMMED AND RECONFIGURED**
- **FURTHER, IT MUST BE MULTIFUNCTIONAL IN SUPPORTING VARIOUS SW STANDARDS, AND 'FUTURE PROOF' IN IMPLEMENTING ANY FUNCTION IN REAL-TIME WITHOUT THE NEED TO CHANGE ITS HARDWARE**
- **USING SDR, ONE CAN TURN HIS/HER RADIO INTO MOBILE CELLULAR DEVICE, WI-FI HOTSPOT, OR EVEN AN FM RADIO!**

WINNFORUM - SDR FORUM

ESTABLISHED IN 1996, WINNFORUM IS RESPONSIBLE FOR PROMOTING SDR STANDARDS & TIERS, MAKING REUSE OF THE SAME SW POSSIBLE. ALSO FOSTERS COLLABORATION AMONGST SDR ADOPTERS.

THE FORUM HAS PROVIDED TWO MAIN TYPES OF RADIO CONTAINING SOFTWARE:

- 1. SOFTWARE CONTROLLED RADIO: RADIO WITH PHYSICAL LAYER FUNCTIONS THAT ARE SOFTWARE-CONTROLLED**
- 2. SOFTWARE-DEFINED RADIO: RADIO WITH PHYSICAL LAYER FUNCTIONS THAT ARE ENTIRELY DEFINED BY SOFTWARE. THIS MAY BE IMPLEMENTED BY WAY OF OBJECT-ORIENTED PROGRAMMING**

SDR LEVELS⁶

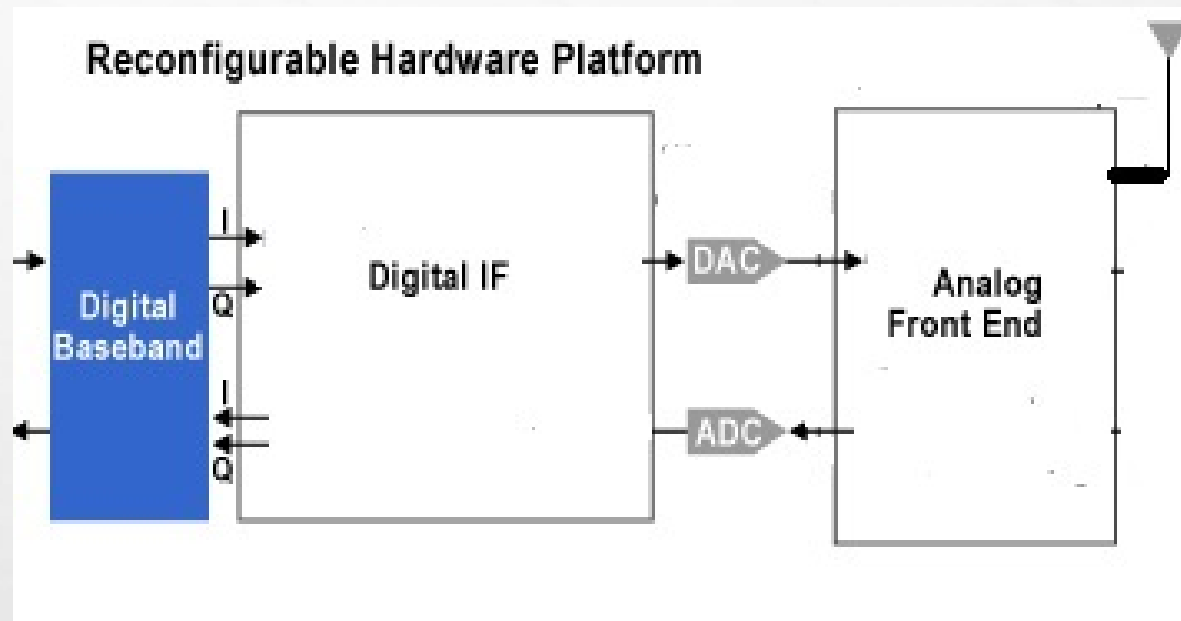
- **VARIOUS TIERS EXIST IN SDR, NAMELY:**
 - **TIER 0 – A NON-CONFIGURABLE RADIO**
 - **TIER 1 – SOFTWARE-CONTROLLED RADIO WITH LIMITED FUNCTIONALITY CAPABILITIES**
 - **TIER 2 – SDR WHERE SIGNIFICANT PROPORTION OF THE RADIO IS SW RECONFIGURABLE**
 - **TIER 3 – IDEAL SDR WHERE RF FRONT-END IS RECONFIGURABLE, HENCE, RADIO HAS FULL PROGRAMMABILITY**
 - **TIER 4 – ADVANCED SDR WHERE RADIO IS FULLY PROGRAMMABLE BUT ALSO SUPPORTS ADDITIONAL FEATURES SIMULTANEOUSLY**



HARDWARE IMPLEMENTATION

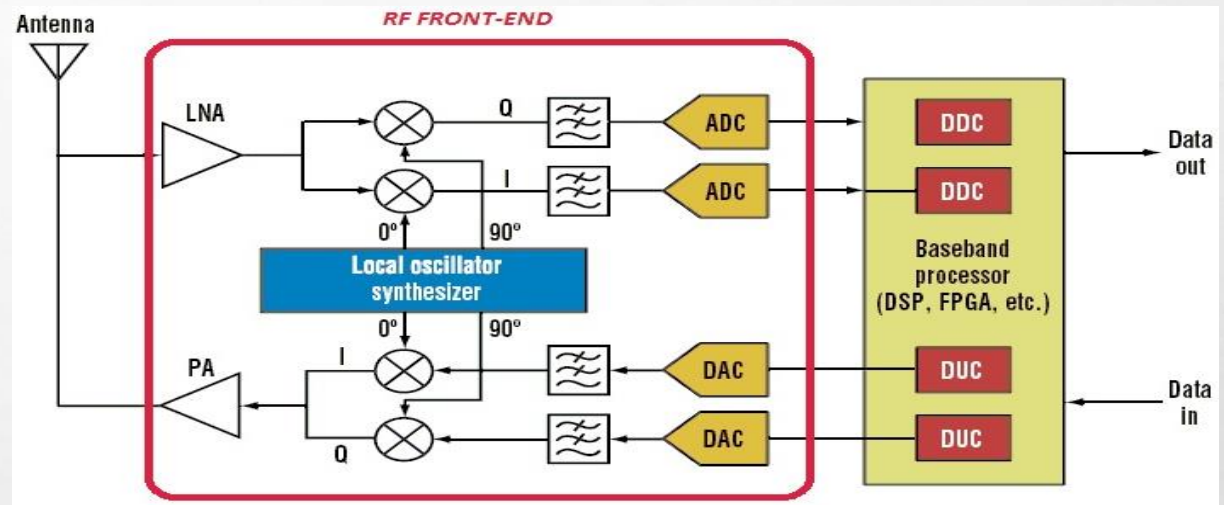


SDR ARCHITECTURE



- **MODERN COMMUNICATIONS SYSTEMS DEMAND MORE INFORMATION CAPACITY AND BETTER SIGNAL QUALITY HENCE DIGITAL MODULATION IS UTILIZED AT BASEBAND GENERATING I/Qs**
- **BASEBAND PROCESSES INPUTTED DATA ACCORDINGLY, TAKING CARE OF MODULATION, FILTERING ETC. IQ MODULATION SCHEME IS WELL-SUITED FOR DIGITAL MODULATION**
- **DIGITAL IF CONTROLS THE RF FRONT-END TO PERFORM THE NECESSARY RF FUNCTIONS**

ANALOG RF FRONT-END FOR SDR



- **WIDEBAND FRONT-END RADIO IS CONTROLLED BY INTERMEDIATE FREQUENCY (IF) SO AS TO MEET BASEBAND PROCESSING DEMANDS**
- **MIXERS IN THE PASSBAND MAY BE PROGRAMMED TO PRODUCE DESIRED CARRIER FREQUENCY OF OPERATION**
- **EXAMPLE: AD9361, SHOWN ABOVE, DEVELOPED BY ANALOG DEVICES; READILY AVAILABLE SDR PROTOTYPING VIA DSP INTERFACE**

BASEBAND PROCESSING

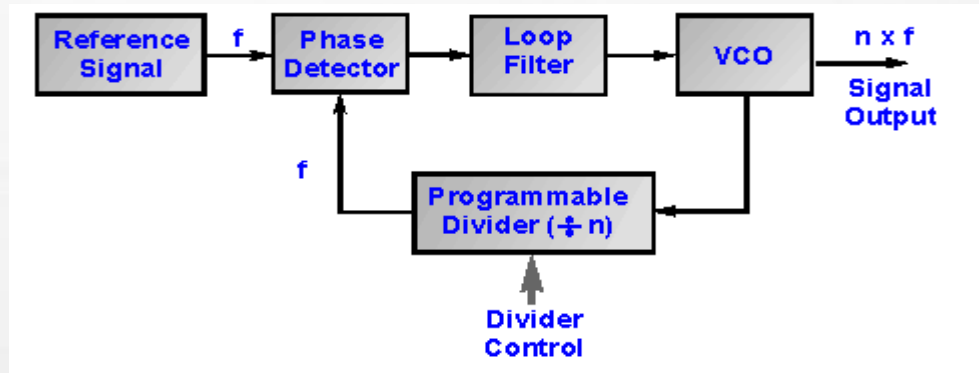


- **TO IMPLEMENT SDR, HIGH-SPEED DSPS AND FPGAS, ARE PRIMARILY USED SO AS TO MEET ABUNDANT BASEBAND PROCESSING DEMANDS OF SDR**
- **DUE TO THE HIGH AMOUNT OF PROCESSING REQUIRED, HIGH-SPEED DSPS AND FPGAS ARE UTILIZED**
- **EXAMPLES : DSP TMS320C541, ABOVE, DEVELOPED BY TEXAS INSTRUMENTS**

PROGRAMMABLE FREQUENCY SYNTHESIS

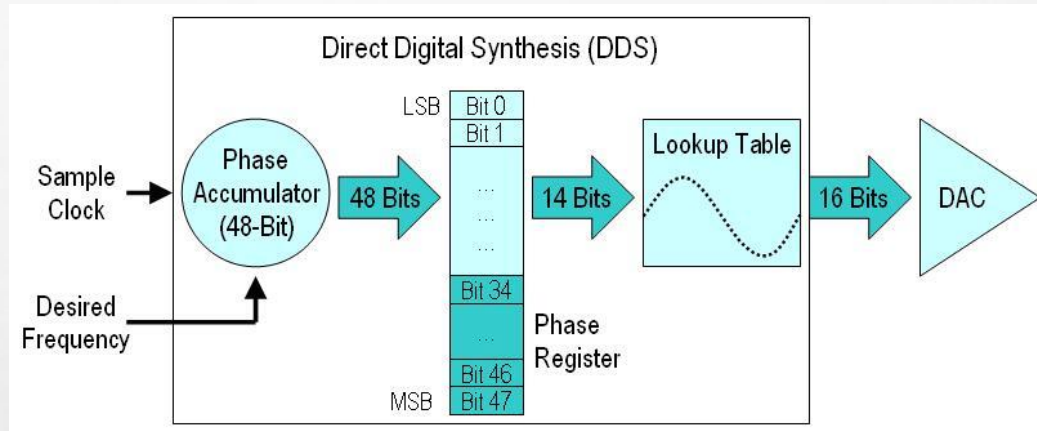
- **VOLTAGE-CONTROLLED OSCILLATORS, VCO, ARE USUALLY EMBEDDED IN A FREQUENCY SYNTHESIS ENVIRONMENT SO AS TO GENERATE A RANGE OF USABLE RF FREQUENCIES**
- **STRINGENT STANDARDS MUST BE ADHERED TO SO AS TO UTILIZE FREQUENCY SPECTRUM, MAKING FREQUENCY ACCURACY AND PRECISION IMPORTANT PARAMETERS TO SATISFY**
- **THERE ARE THREE MAIN METHODS IN SYNTHESIZING FREQUENCIES:**
 - **DIRECT ANALOG SYNTHESIS (DAS)**
 - **DIGITAL PHASE-LOCKED LOOPS (PLL) SYNTHESIS**
 - **DIRECT DIGITAL SYNTHESIS (DDS)**
- **OF THE THREE METHODS, THE LATTER TWO SERVE AS PREFERRED IMPLEMENTATIONS OF FREQUENCY SYNTHESIS: DIGITAL PLL SYNTHESIS LOCK INTO DESIRED CHANNELS, DDS USES DIGITAL MEANS TO GENERATE FREQUENCIES**
- **DIRECT ANALOG SYNTHESIS, DAS, IS NOT SUITABLE FOR PORTABLE EQUIPMENT DUE TO THEIR BULKY SIZE AND COST**

DIGITAL PLL SYNTHESIZERS¹¹



- **DIGITAL PLL SYNTHESIZERS ARE PERHAPS THE MOST WIDELY USED FREQUENCY SYNTHESIZERS DUE TO THEIR SPECTRAL PURITY AND LEAST COST. ABLE TO LOCK INTO A RANGE OF FREQUENCIES**
- **OFFERS FINE FREQUENCY RESOLUTION AND LOW SPURIOUS OUTPUTS –DRIVEN BY A CRYSTAL FREQUENCY SOURCE**
- **GENERATES A CLEAN AND STABLE LO FREQUENCY FOR FREQUENCY TRANSLATION**
- **USED IN A VARIETY OF PRODUCTS FROM CELLPHONE CHIP SETS TO MILITARY RADIO APPLICATIONS AND PRODUCTS**
- **DIVIDER CONTROL SIGNALS MAY ORIGINATE FROM BASEBAND PROCESSOR FOR CONTROL AND SWITCHING**
- **DISADVANTAGE: SLOW FREQUENCY SWITCHING TIME; POOR TRANSIENT RESPONSE – HENCE NOT SUITED FOR SDR**

DIRECT DIGITAL SYNTHESIS, DDS¹²



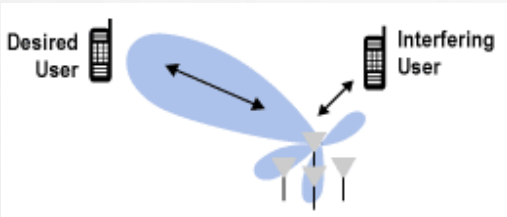
- **DDS GAINING IMPORTANCE IN DIGITAL COMMUNICATIONS DUE TO ITS SUPERIOR PRECISION, STABILITY, AND FAST FREQUENCY SWITCHING**
- **DDS USED IN FREQUENCY HOPPING SPREAD SPECTRUM, FHSS, SYSTEMS, IN CELL PHONES OR MILITARY RADIO PRODUCTS**
- **DIRECT DIGITAL SYNTHESIS MAKE IT POSSIBLE TO USE DIGITAL MODULATION METHODS**
- **DDS CHIPS OFFER HIGH PRECISION AND STABILITY; EASY TO INTERFACE WITH PROCESSORS FOR CONTROL. IN ADDITION USED TO FORM ARBITRARY AND CUSTOMIZED WAVEFORMS; ESSENTIAL FOR SDR**

MULTIBAND ANTENNAS



- **ANTENNAS ARE THE WEAKEST LINK IN SDR SINCE ANTENNAS ARE INHERENTLY NARROWBAND DEVICES AS THEY'RE DESIGNED TO RESONANT AT A SINGLE FREQUENCY**
- **HENCE, 900MHZ TO 2GHZ FREQUENCY BAND IS DIFFICULT TO SUPPORT USING A SINGLE ANTENNA**
- **IN PRACTICE, MULTIPLE NARROWBAND ANTENNAS ARE COMBINED TO FORM A MULTIBAND ANTENNA ARRAY**
- **MULTIBAND ANTENNAS SUPPORT A RANGE OF FREQUENCIES SUITED FOR WIDEBAND COMMUNICATIONS**

SMART ANTENNAS



- **SMART ANTENNAS ARE ANTENNA ARRAYS THAT CAN BE DESIGNED AND RECONFIGURED TO FOCUS AND CAPTURE DESIRED SIGNAL, WHILE ATTENUATING OTHERS**
- **OPERATES BY SENSING TARGET USING A DSP-DRIVEN ALGORITHM**
- **SDR AND SMART ANTENNAS COMPLEMENT ONE ANOTHER AS BOTH ARE DEPENDENT ON THE DSP FOR RECONFIGURATION**
- **SMART ANTENNAS MOTIVATE SDR DESIGNERS TO COME UP WITH NEW ALGORITHMS FOR IMPLEMENTATION**

UNIVERSAL SOFTWARE RADIO PLATFORM, USRP



- **DEVELOPED BY ETTUS RESEARCH. PERHAPS CONSIDERED BY MANY TO BE THE 'IDEAL' SDR ON THE MARKET TODAY**
- **WORKS WITH THE GNURADIO AND OPENBTS TO SUPPORT THE OPEN-SOURCE USRP**
- **FEATURES: WIDEBAND RF (70MHZ – 6GHZ), FULLY DUPLEX (MIMO), USB INTERFACE**



SDR USAGE & BENEFITS



SDR BENEFITS

- **BESIDES BEING ABLE TO SUPPORT VARIOUS AIR-INTERFACE STANDARDS, SDR CAN BE PROGRAMMED TO PROCESS OTHER FEATURES I.E. FM, WI-FI, BLUETOOTH, MILITARY TRACKING CAPABILITIES ETC**
- **DUE TO ITS FLEXIBILITY IN RECONFIGURATION, SDR IS VERY USEFUL IN THE PROTOTYPING DESIGN PHASE**
- **COST-EFFECTIVE SOLUTION IN DEPLOYING EQUIPMENT, EG. UPGRADES CAN SIMPLY BE DONE BY WAY OF SW**
- **INEXPENSIVE WAY TO PROTOTYPE NEXT-GENERATION WIRELESS APPLICATIONS**

EASE OF SW UPDATES



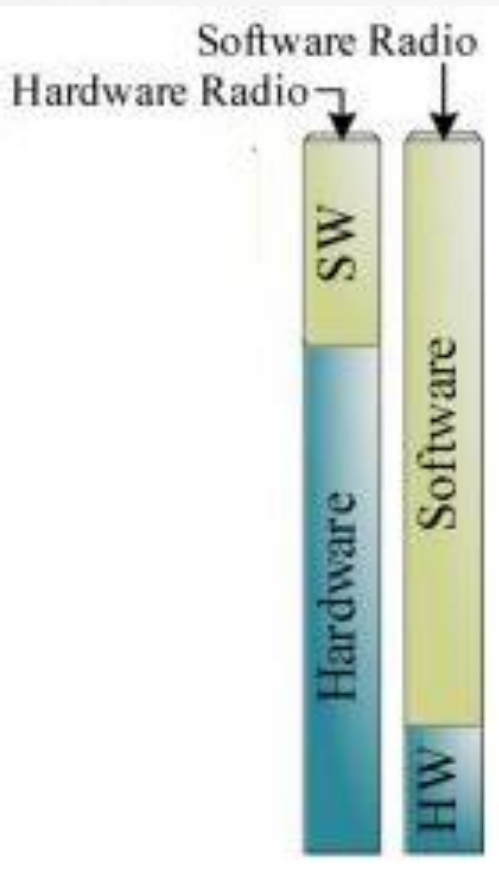
- **DEVICE SW UPDATES MAY BE ACCOMPLISHED BY WAY OF OVER-THE-AIR PROGRAMMING, OTA, METHOD FREQUENTLY USED BY MOBILE OPERATORS**
- **UPDATING THE RF MODULE, EASILY ACHIEVED, BY SIMPLY DOWNLOADING THE BASEBAND MODULE FIRMWARE**



SDR APPS & FEATURES



MULTIMODE CELLULAR



- **CLASSICAL MULTIMODE CELLPHONES INTEGRATE SEVERAL 'DEDICATED' TRANSCEIVERS TO PROVIDE SERVICES WHICH USE UP MORE HARDWARE**
- **USING AN SDR APPROACH, LESS HARDWARE IS UTILIZED, HENCE SW USED TO IMPLEMENT MULTIMODE CELLULAR CONNECTIVITY**

TRACKING SDR APP



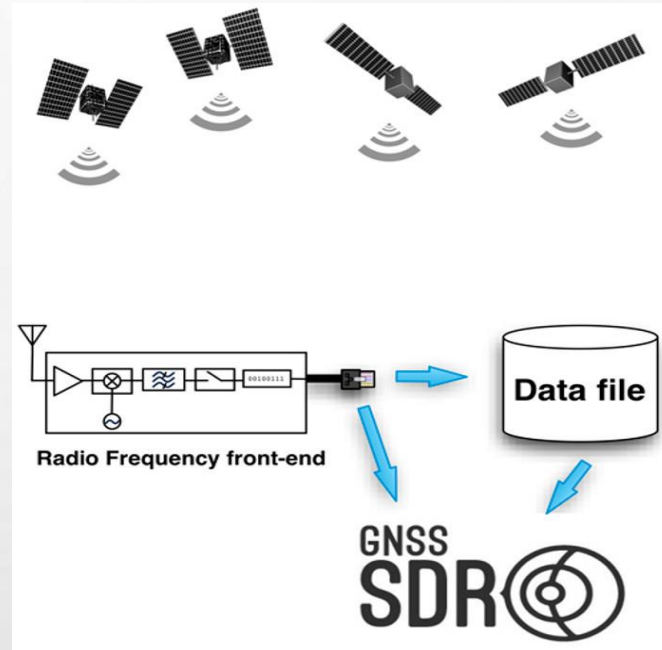
- **AUTOMATIC ID SYSTEM, AIS, WHICH IS USED TO IDENTIFY AND TRACK VESSELS**
- **MODE S, WHICH IS SIMILAR TO AIS, IN TRACKING AIRCRAFTS; AIRCRAFT POSITIONS PLOTTED ONTO GOOGLE EARTH**

FM RADIO



- **SDR MAY BE PROGRAMMED TO RECEIVE BROADCAST RADIO OVER-THE-AIR; THIS IS ACCOMPLISHED BY PUTTING TOGETHER AN FM RADIO APP**
- **USRP MAY BE UTILIZED TO REALIZE FM RADIO FEATURE**

GPS FUNCTIONALITY – GNSS SDR



- **USING THE GLOBAL NAVIGATION SATELITE SYSTEMS, GNSS, TO FURTHER EXPLORE GPS FUNCTIONALITY**
- **GNSS PROVIDES A FREE OPEN-SOURCE CODE FOR GPS SDR APPLICATION**

WI-FI FUNCTIONALITY



- **USING SDR, 802.11 STANDARD MAY BE REALIZED IN THE ISM BAND**
- **RADIO TUNES INTO THE 2.4GHZ FREQUENCY BAND AND PROCESSED BY THE DSP TO MEET WIRELESS STANDARD SPECIFICATIONS**

WIRELESS INNOVATION



- **ONE MAY INVENT NEW WAYS AND ALGORITHMS TO IMPLEMENT NEW WIRELESS STANDARDS; EXPERIMENT WITH NEW TECHNOLOGIES AND FEATURES**
- **THIS IS ACCOMPLISHED IN A COLLABORATIVE MANNER AMONGST FORUM MEMBERS**

FUTURE WIRELESS



dreamstime.com

'UNIVERSAL' HANDSET

- **'UNIVERSAL' HANDSETS ARE SDR-BASED HANDSETS, WHICH ARE CAPABLE OF SUPPORTING COUNTLESS FEATURES TO INCLUDE FM, WI-FI, EVEN A FEATURE THAT DOESN'T EXIST! - ALL USING A SOFTWARE RADIO PLATFORM!**
- **THIS MAY ENTAIL TURNING YOUR CELLPHONE INTO A MOBILE TV SET**
- **IN THE FUTURE, HANDSETS AND WIRELESS DEVICES WILL BE REQUIRED TO SUPPORT MORE AND MORE FEATURES AND SERVICES FOR THE END-USER**
- **WITH THIS GROWING DEMAND COMES A NEED FOR RECONFIGURABLE RADIOS THAT MAY BE UPGRADED SIMPLY BY MEANS OF SW I.E. WIRELESS OPERATOR-CONTROLLED OTAS, WITHOUT HAVING TO REPLACE DEVICE**
- **THIS WOULD BE A MORE COST-EFFECTIVE SOLUTION FOR THE CONSUMER IF THEY WISH TO UPGRADE TO A LATER SERVICE**

COGNITIVE RADIO

- **CONCEPT PROMOTED BY MITOLA IN 1999 IN COLLABORATION WITH GERALD MAGUIRE JR., OF THE ROYAL INSTITUTE OF TECHNOLOGY, DESCRIBING IT AS AN 'ADVANCED' SDR CAPABLE OF SELF-RECONFIGURATION BASED ON SURROUNDINGS AND RF ENVIRONMENT**
- **MAY SELF-ADJUST OUTPUT TRANSMIT POWER, ADAPT TO RF ENVIRONMENT; ALL IN AN AUTONOMOUS FASHION**
- **A RADIO INTELLIGENT ENOUGH TO RECONFIGURE ITSELF, BY DETECTING AND CLAIMING FREQUENCY SPECTRUM, WOULD BE CLASSIFIED AS A 'TRUE UNIVERSAL HANDSET'!**

SUMMARY

- ✓ **CONCEPT FIRST CONCEIVED BY JOE MITOLA IN 1991. HE LATER DUBBED IT SOFTWARE-DEFINED RADIO, SDR**
- ✓ **SDR UTILIZES BASEBAND TO CARRY OUT THE MAJORITY OF ITS RADIO FUNCTIONS (SW-BASED) I.E. DEMOD/MODULATION, SW PROTOCOLS (STANDARD COMPLIANCE) IMPLEMENTED BY WAY OF CODING**
- ✓ **IN SDR, RF FRONT-END (TRANSCIVER CHIP SET) CONSTITUTES A SMALL PORTION OF RADIO FUNCTIONS. RADIO MAY BE RECONFIGURED USING BASEBAND TO PROVIDE ITS PARAMETER CHANGES, I.E. FREQUENCY SWITCHING, POWER CONTROL**
- ✓ **TRANSCIVER RADIO FUNCTIONS ARE CONTROLLED BY IF, SERVING AS AN INTERFACE BETWEEN BASEBAND AND RF FRONT-END; PROCESSING CONTROL SIGNALS AT IF**
- ✓ **FURTHER, DATA PROCESSED AT BASEBAND, USING HIGH-SPEED DSP/FPGA, WHICH DELIVER A WIDE RANGE OF FUNCTIONALITIES TO THE END-USER**
- ✓ **SUPPORTS A MULTITUDE OF FEATURES NAMELY MOBILE CELLULAR, GPS, WI-FI**
- ✓ **THE ADVENT OF SDR REVOLUTIONIZED THE WIRELESS CELLULAR ARENA AND CONTINUES TO PLAY A VITAL ROLE IN THE IMPLEMENTATION AND EXPLORATION OF NEW SW FEATURES, WHICH IS ESPECIALLY USEFUL DURING THE PROTOTYPING DESIGN PHASE**
- ✓ **THE DEPLOYMENT OF MORE AND MORE FEATURES ENTAILS THE NEED FOR AN ADAPTABLE AND RECONFIGURABLE RADIO – SDR MEETS THIS CRITERIA!**
- ✓ **FUTURE WIRELESS EQUIPMENT MAY ENTAIL 'COGNITIVE RADIO', WHICH IMPLIES A RADIO THAT RECONFIGURES ITSELF IN AN AUTONOMOUS FASHION**

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